Red Rot in Residual Ponderosa Pine Stands on the Navajo Indian Reservation

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Red Rot in Residual Ponderosa Pine Stands on the Navajo Indian Reservation[1]

by

Paul C. Lightle and Stuart R. Andrews,

Principal Plant Pathologists

Rocky Mountain Forest and Range Experiment Station[2]

[1] Results of a study made in cooperation with the Bureau of Indian Affairs and the Navajo Tribe. Many Bureau and Tribal employees participated in the field work, but the authors are particularly indebted to: Kenneth Bowman, M. C. Collins, Elgin Filkins, Tom Notah, Roger Ramsey, and Reino Sarlin. In addition to providing personnel and study areas (including merchantable timber), the Tribe made substantial financial contributions under the provisions of a Cooperative Agreement between it, the Bureau of Indian Affairs, and the Rocky Mountain Forest and Range Experiment Station.

[2] Central headquarters maintained in cooperation with Colorado State University at Fort Collins. Lightle is located at Albuquerque in cooperation with the University of New Mexico.

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Red rot caused by Polyporus anceps Pk. is the major defect of merchantable ponderosa pine (Pinus ponderosa Laws.) in Arizona and New Mexico. It accounts for 15 to 25 percent of the gross sawtimber volume harvested from virgin stands. [3] Significance of red rot in first cuttings has been recognized for many years, but the only source of information on losses that can be anticipated in second cuts is a single study made in 1939. [4] Results of the 1939 study were not representative of the region as a whole, and were based on heavier initial cuts than are currently being made under the light improvement selection system. They suggested that red rot losses in second cuts would amount to about half those sustained in the original operation, and would decline with each subsequent cutting. Magnitude of the losses, however, depends not only on age classes originally present in the stands, but also on the extent to which mature and overmature trees contribute to later cuts. [3]

Interest in the red rot problem in residual stands began in 1947 with adoption of lighter cuts by most forest-resource-managing agencies in Arizona and New Mexico. Greatest concern was expressed by the U. S. Bureau of Indian Affairs (BIA) shortly after the light improvement selection system was introduced on the Navajo Indian Reservation in 1951. Timber removed by this system contained less cull than timber removed under the old cutting policy designed to remove 55 percent of the gross volume.[5] BIA foresters therefore suspected that the residual stand contained more defect than was left after the older harvests. For this reason BIA recommended that red rot be studied in the Defiance Logging Unit of the Reservation. A cooperative study was started in 1955 and completed in 1956. It was extended to the Chuska-Tsailee Unit in 1959 and 1960.

The study objective was to determine the significance of red rot in residual ponderosa pine stands after a first cut under the light improvement selection method. The following information was collected:

1. Proportion of red rot in the virgin stand, in the trees that were removed in the first cut, and in the residual stand.
2. Relationships of red rot to stand location and density, and to tree age, vigor, size, risk classification, and other external features of trees.
3. Red rot losses that can be anticipated in the second cut.

Study Methods

The study was limited to about 7,000 acres of the Defiance Unit and to about 31,000 acres in the Chuska-Tsailee Unit. Acreages in 3-bar-density[6] strata were determined from planimetric maps. Twenty plot clusters in the Defiance Unit and 75 in the Chuska-Tsailee Unit were located at random in proportion to the areas of the strata (fig. 1).

Clusters of four 1/4-acre circular plots were used in the Defiance Unit. If a cluster was located in a stand not already marked for cutting, one of the BIA foresters marked an area of at least 5 acres that included the

[3] *Andrews, Stuart R. Red rot in ponderosa pine. U. S. Dep. Agr., Agr. Monogr. 23, 34 pp., illus. 1955.*

[4] *Chapel, William L. Unmerchantability in second cut ponderosa pine. J. Forest. 40: 45-48. 1942.*

[5] *Clark, Don W., and Melis, Percy E. A master plan for timber management. Navajo Indian Reservation, U. S. Bur. Indian Affairs. 74 pp., illus. 1953.*

[6] *As defined in the Timber Management Plan for the Navajo Reservation, 0-bar density has 0 to 10 percent of the ground surface covered by tree crowns of coniferous species, 1-bar has 10 to 25 percent cover, 2-bar has 25 to 45 percent cover, and 3-bar has 45 to 75 percent cover (see footnote 5).*

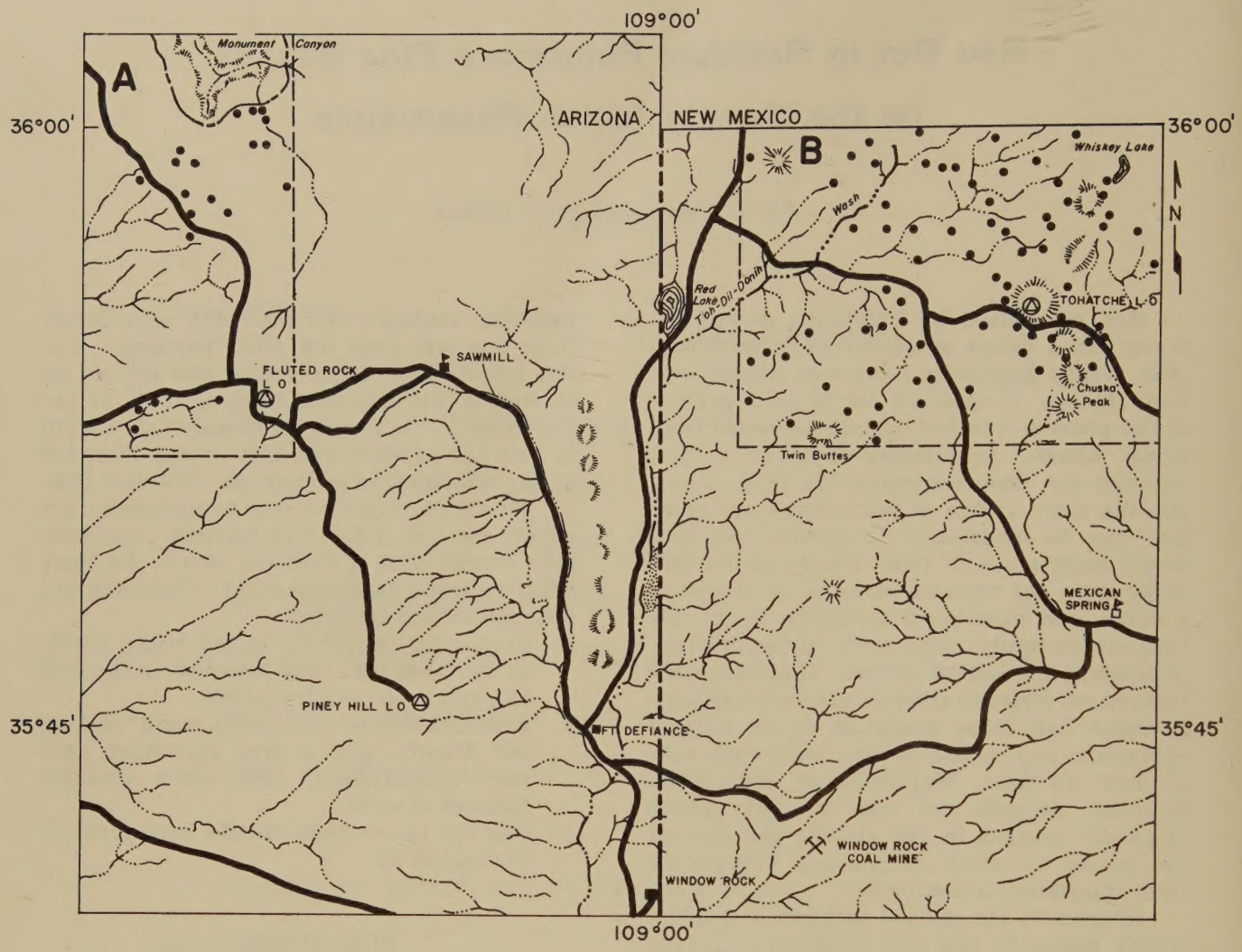


Figure 1.--Approximate location of four-plot clusters in the cutting area of the Defiance Logging Unit (A) and two-plot clusters in the Chuska-Tsailee Logging Unit (B), Navajo Indian Reservation.

cluster.[7] In the Chuska-Tsailee Unit, clusters of two 1/4-acre circular plots were used. Here an area of at least 3 acres was laid out and marked by the BIA foresters (fig. 2).

The following information was recorded for all living merchantable-sized trees:

1. To be cut or reserved
2. Marking criteria, such as diameter at breast height (d.b.h.), merchantable height in 16-foot logs, Keen classification,[8] and risk rating; [9]

[7] *Trees were marked by two overlapping methods: (a) to a fixed standard by Keen Tree Classes to remove an average of 35 percent of the stand in the older age and lower vigor classes, and (b) comparison of individual trees to accomplish the same result (see footnote 5).*

[8] *Keen Age Classes are: I - less than 75, II - 76-150, III - 151-225, and IV - more than 225 years old. (Thomson, Walter G. A growth rate classification of southwestern ponderosa pine. J. Forest. 38: 547-553. 1940.)*

[9] *Salmon, K. A., and Bongberg, J. W. Logging high-risk trees to control insects in pine stands of northwestern California. J. Forest. 40: 533-539. 1942.*

3. External defect and symptoms of disease other than rot;
4. Decayed branch stubs suspected of being red rot entrance points;
5. Characteristics of bark in the butt log as a possible indication of age, or proclivity to decay.

After trees marked for cutting on the Defiance plots had been felled, bucked into saw logs, and scaled (Scribner Decimal C Rule) by a BIA scaler, they were set aside for regular commercial utilization. The remaining merchantable trees on the study plots were felled and also bucked and scaled as saw logs. Then, however, they were completely dissected to determine the actual amount of red rot present. On the Chuska-Tsailee study plots, all trees were felled, bucked, scaled, and dissected.

Logs were scaled (including deductions for defect)[10] under optimum conditions. Practically all trees were scaled immediately after bucking while logs were still in position, except for slight displacement to enable the scaler to see and make necessary measurements on the log ends. Faces of cuts usually were moist and clean, and even small areas of discoloration or incipient decay could be seen with little difficulty. Age (determined by ring counts at stump height), log dimensions, gross and net scale, deductions for defect listed separately for red rot and other rots, and other measurements made during log scaling and dissection were noted (figs. 3, 4). The volume of wood actually decayed by red rot was ascertained in order to:

1. Get an accurate measurement of rot that was not influenced by the scalers' judgment or experience.
2. Determine if current scaling practice provided sufficient allowance for visible red rot to offset losses from hidden decay.

Actual red rot volumes and losses of associated sound wood less than 6 feet long were derived from profiles of decay columns. A factor of 10 was used in converting cubic feet to board foot volume.

[10] *Deductions for rot were made by the square-defect method. Where red rot showed on both ends of a log, the largest squared dimension was used and the rot considered to extend the full length of the log. If red rot showed on only one end of a 16-foot log, the decay was scaled as though it extended 8 feet. Red rot showing on one end of logs less than 16 feet long was considered to run the full length of the log. These estimates of the lengths of red rot columns were modified where there were definite indications that other rot column lengths should be used.*

Results and Discussion

Table 1 summarizes important characteristics of the sampled stands on the Defiance and Chuska-Tsailee Logging Units, including accuracy of the sampling estimates. Standard errors are shown only for gross volume per acre and percent of red rot. Other standard errors have been omitted, but their precision is similar to the ones shown. Since each unit was sampled independently, and no overall estimates were planned, the combined estimates

Figure 2.--Marking timber in 3-acre area that includes a two-plot cluster in the Chuska-Tsailee Logging Unit of the Navajo Indian Reservation.

Figure 3.--Logs from a study tree have been bucked into 4-foot sections to facilitate measurement of rot columns, including rot that may not have shown on the ends of saw logs. A Navajo Indian scaler employed by the Bureau of Indian Affairs measures the cross section of a rot column.

shown in table 1 are simply weighted averages based on the total area of each unit; the variances are approximately the same.

Red rot was widespread in the virgin stands of the study areas. It was present in scalable amounts on 98 percent of the clusters, 78 percent of the plots, and in 36 percent of the trees. This rot amounted to 15 percent of gross scale and, alone, made up 68 percent of the total defect in the virgin stands.

Red rot cull percentages were almost identical on the two logging units, but average gross volumes per acre were appreciably higher for the Defiance Unit (table 1). The study areas in this unit contained older trees and a proportionately larger sample in the 2-bar density class, which had the highest gross volume per acre. For general application, however, the results were combined.

Relation of red rot to stand density.— Red rot cull percentage was appreciably higher (19) in the 0-bar density class than in either the 1-bar (15) or 2-bar (14) classes. Since bar density classes are delineated on planimetric maps prepared from aerial photographs, this red rot-crown density relationship may be of considerable practical significance.

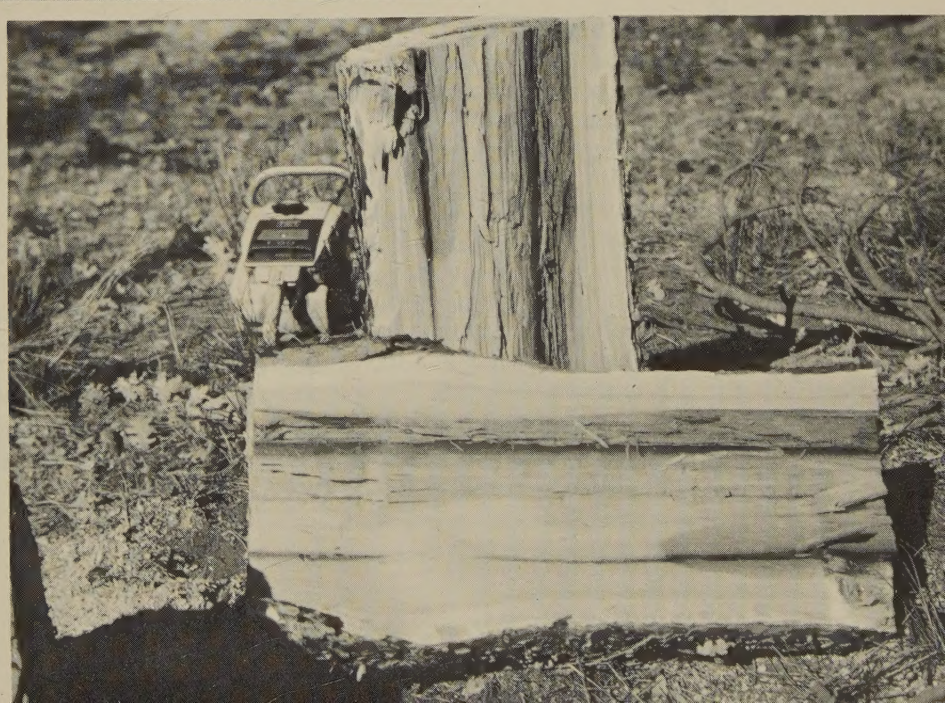
Table 1. --Comparison of timber stands on the Defiance and Chuska-Tsailee Logging Units

Logging Unit	Virgin stand				Cut		
	Gross volume	Defect: Proportion of virgin stand			Cut: Proportion of virgin stand	Defect: Proportion of defect removed by cutting	
		Total	Red rot	Red rot: Proportion of total defect		Total	Red rot
	Mbm/acre	Percent					
Defiance	6,122 ± 684	21	15 ± 1	69	43	56	51
Chuska-Tsailee	4,922 ± 484	22	15 ± 2	68	51	80	76
Combined	5,149 ± 495	22	15 ± 2	68	48	72	68

Figure 4.--Tree dissection reveals characteristic red rot:

Complete destruction of heartwood in advanced stage of decay near point of entrance for rot.

Scattered small pockets of incipient decay near the limits of a rot column.



Final step in dissection is splitting 4-foot sections to determine upper and lower limits of individual rot columns.

Relation of red rot to age.—Actual ages were determined for all but a few badly decayed trees, and it was possible to show the relationship of average gross volume per tree and red rot cull percent to age. Figure 5 shows this relationship for the virgin and residual stands by 20-year age classes. There is little difference between the gross volume curves for the virgin and residual stands between 80 and 260 years, but the curve for red rot cull percent in the residual stand is 1 to 2 percent below the virgin stand curve. These relationships probably reflect quite well the effect of the cut, which removed proportionally more red rot volume than gross volume.

Early in the study, it was noted that many trees classified as Keen Age Class III according to bark color on the upper trunk and crown characteristics,[8] were older than 225 years on the basis of stump ring counts. Although no attempt was made to discover underlying causes for this, it was apparent that consistent underestimates of age would lead to an erroneous impression of the age-class structure of the stand, which would in turn obscure the fundamental relationship between red rot and age basic to an understanding of rot development in the residual stand. This effect is illustrated in figure 6, which compares the distribution of gross and red rot volumes in Keen Age

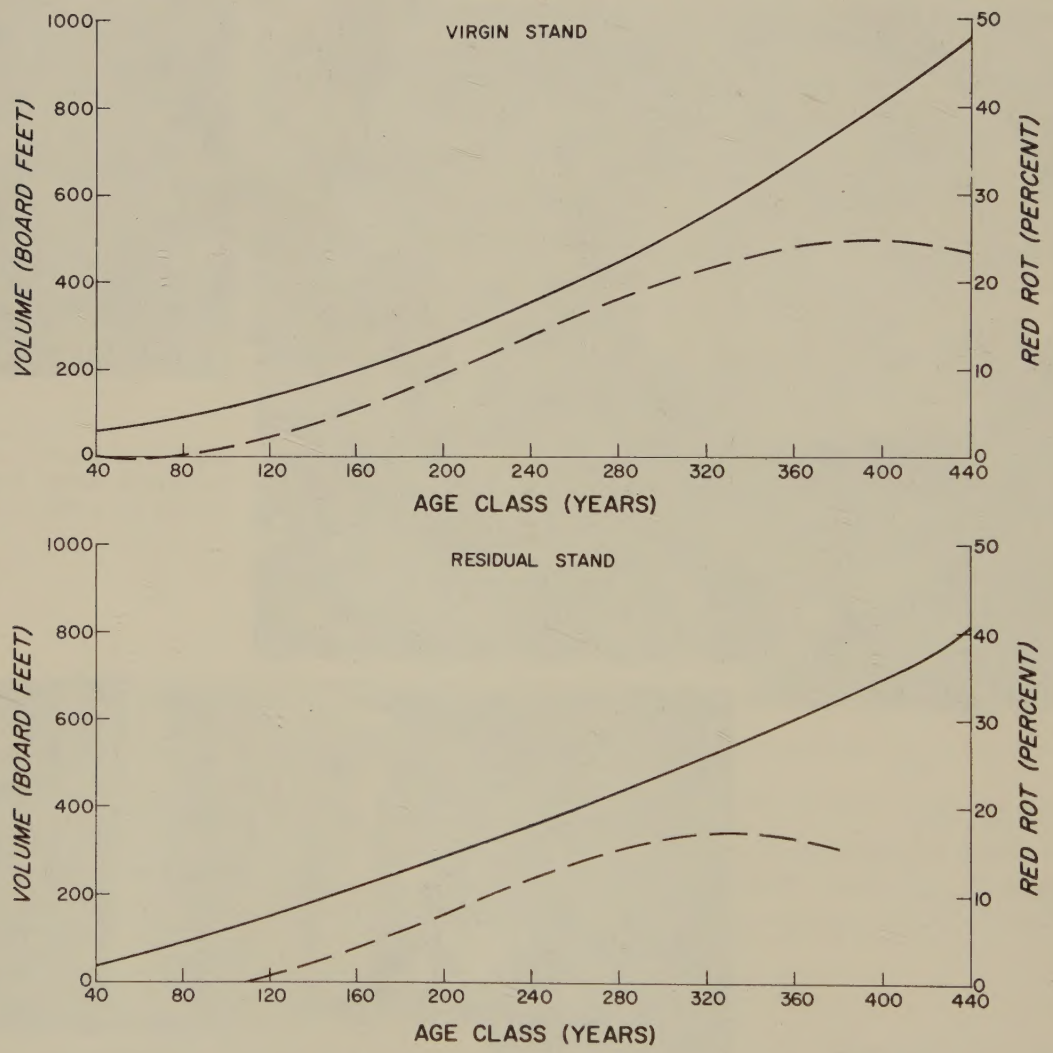


Figure 5.--Relation of average gross volume per tree (solid line) and red rot cull percent (broken line) to age for the virgin stand and the residual stand.

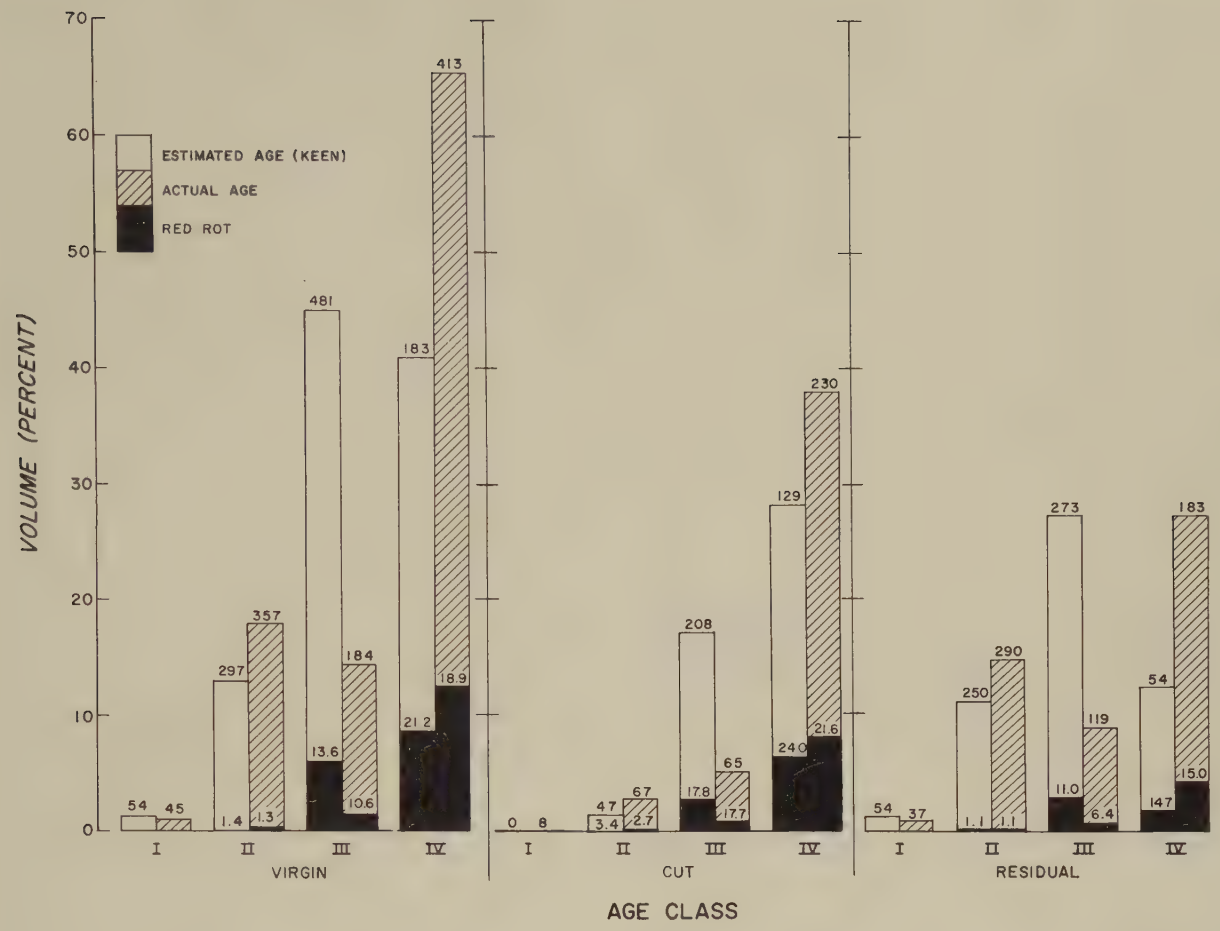


Figure 6.--Distribution of gross volumes and scaled red rot volumes in the virgin, cut, and residual stands according to estimated and actual age. (Number above bars are trees in samples; those within bars are red rot cull percents--not shown where red rot proportion was too small to plot.)

Classes based on estimated and actual age in the virgin stand, the cut, and the residual stand.

For the virgin stand (fig. 6) estimated age seems to indicate a better than average age class distribution for old-growth ponderosa pine: both Age Classes III and IV contained more than 40 percent of the gross volume of the stand, and an initial cut concentrated in the older age class should leave a substantial volume in younger age classes for the second cut. Actual ages, however, present a less favorable picture: about 14 percent of the gross volume was actually in Age Class III, whereas about 66 percent was in Age Class IV, an imbalance that could be only partly corrected by the cut. Reclassification of the trees according to actual ages did not have such a pronounced effect on the distribution of red rot in these two age classes, although it did reduce cull percent in Age Class III from 13.6 to 10.6.

Despite the tendency to underestimate tree ages during marking, trees removed in the first cut contained more red rot than the average for the virgin stand, thus leaving a less defective residual stand as the basis for a second cut. While this was true for both Age Classes III and IV, whether or not the trees were properly classified, it was particularly evident for trees placed in Age Class III according to actual age (fig. 6). Presumably,

many decayed trees in this class were marked for removal under the current policy because of some external characteristics.

Volume distribution in the residual stand (fig. 6) suggests that mature and overmature trees in actual Age Class IV rather than Age Class III, will provide most of the volume for the second cut. Age Class IV with 15 percent of the gross volume already destroyed by red rot provides a more realistic basis for estimating future losses than the heterogeneous Age Class III with 11 percent red rot cull.

Scaled, actual, and hidden red rot.—Scaled red rot and resulting cull percentages proved to be satisfactory for this study, although it had been assumed initially that scalers' deductions might be too erratic for analytical use. Scaled red rot consistently exceeded actual red rot volumes throughout the range of ages included in the study. For the residual stand as a whole, red rot cull percent based on scale deductions was about 1.6 times the percent actually decayed. Such a wide margin for error has been justified as a means of protecting timber operators from unexpected losses associated with hidden decay. Spectacular examples of this type of decay have created a widespread impression that rather serious volume losses are involved. Although red rot was hidden in 11 percent of the decayed logs, these losses were small—about 1 percent—and were more than offset by liberal deductions for visible red rot (table 2).

Scaled red rot deductions are not so liberal as the factor of 1.6 suggests, however, since actual decay volumes do not take into account the inevitable loss of sound wood associated with rot. For the Chuska-Tsailee sample it was possible to approximate such losses by calculating the volume of this sound wood, which could only be sawed into lumber less than 6 feet long. On this basis, the ratio of scaled red rot to actual red rot plus the volume of short-length sound wood was 1.4 to 1.0.

Table 2. --Comparison of scaled and actual red rot volumes expressed as a percent of gross volume of logs with red rot

Decay type	Red rot cull		Log basis	
	Scaled	Actual		
	Pct.		No.	Pct.
Hidden	0	1	71	11
Visible	40	23	572	89
Total	40	24	643	100

Red rot in relation to vigor.—Because of close interrelationships between vigor, size, and age, the most vigorous intermediate and mature trees in a stand usually contain the largest gross volumes and red rot volumes. Figure 7 shows a good relationship between average gross volume and vigor class in Keen Age Classes III and IV. The relationship between red rot and vigor class, however, was not the same in the two age classes. Both average red rot volumes and red rot cull percentages increased as vigor decreased in the younger age class, regardless of whether estimated or actual ages were used (except in Vigor Class D for Actual Age, which included only six trees). In the older age class, on the other hand, average red rot volumes tended to decrease as vigor decreased (except that Vigor Class D trees had greater red rot volumes than Class C trees). Because of large volume differences between vigor classes, red rot cull percentages in the older age class tended to increase as vigor decreased, except that Class A trees had higher percentages than Class B trees. These anomalies in the red rot vigor relationship may be due to the small samples involved, or, in the older age class, to limitations in the system of classification whereby trees that have grown vigorously for most of their lives were given a low vigor rating because of recent changes in the crown.

Figure 7 probably reflects one aspect of red rot that was apparent throughout the course of the study—the rot invades trunk heartwood in small trees sooner than in large trees of the same age. Because the fungus usually has less food supply in smaller dead branches of small trees, it works into branch knots sooner, and these, in turn, represent shorter avenues of entrance than corresponding branch parts in larger trees. Time eventually overcomes these differences between small and large trees, and once established in the trunk the red rot fungus probably progresses more rapidly in larger trees.

Figure 7 indicates that Class IV C and D trees should be removed in the first cutting cycle. Since Class C and D trees made up only 17 percent of the gross volume in estimated Age Classes III and IV, it is obvious that vigor class cannot be considered as the lone marking criterion.

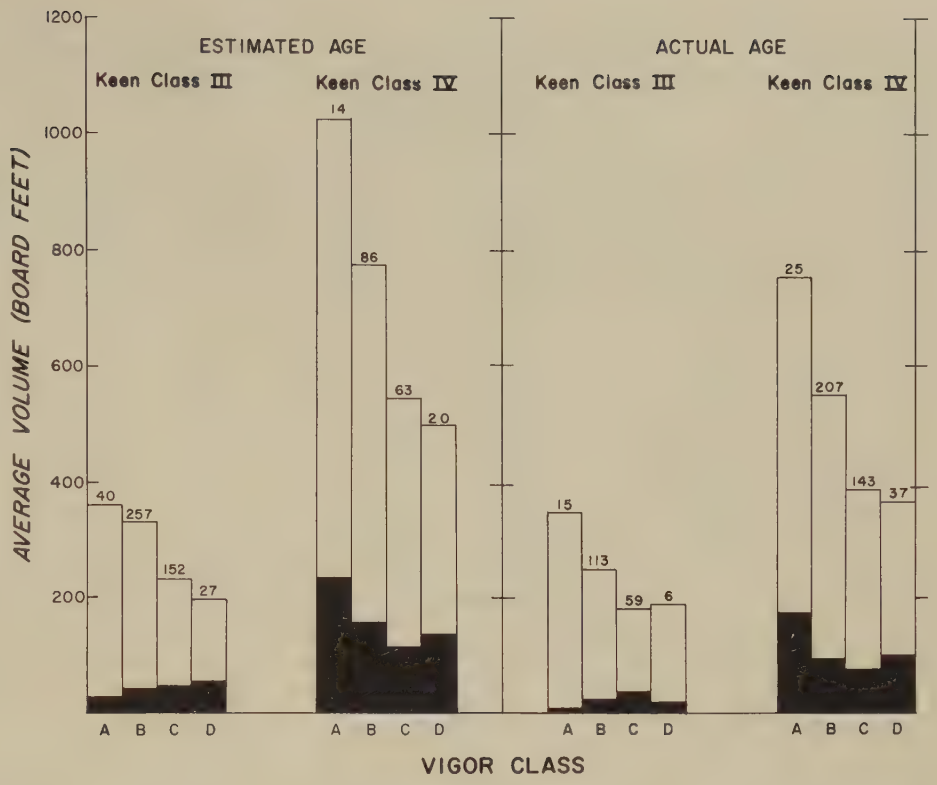


Figure 7.-- Comparison of average gross volumes (clear bars) and scaled red rot volumes (black bars) per tree in the virgin stand by estimated age, actual age, and vigor. (Numbers above bars are trees in samples.)

Red rot in relation to diameter.—Except where sample size was small, red rot volumes increased directly with d.b.h. in Age Class III and IV trees of the virgin stand (table 3). In Age Class III, red rot cull percent decreased as diameter increased because of relatively greater changes in gross volumes than in red rot volumes. In the older age class, however, cull percent was about the same in all d.b.h. classes.

Any relationship between red rot and size, when trees were grouped in broad age classes, is in part attributable to age. This was particularly true in Age Class IV, which included trees varying in age from 226 to more than 400 years. A separate analysis revealed a close relationship between d.b.h. and age for Class IV D trees, as shown in the following tabulation:

	Mean age (Years)
D.b.h. class (inches):	
11.6 - 14.9	265
15.0 - 18.9	279
19.0 - 22.9	293
23.0 - 26.9	301
27.0 - 30.9	350

In spite of the close relationship between red rot and d.b.h., this variable alone does not appear to have any practical implications because diameter classes in which red rot differs significantly from the average usually make up only a minor proportion of total volume of the stand.

Red rot in relation to risk rating.—The purpose of the risk rating system is to provide timber markers with the means to single out trees that are least likely to survive until the following cutting cycle. Characters used in defining risk relate to vigor as judged from appearance of the crown, although some types of tree injuries are appraised independently if they seem to indicate premature death.[9] Table 4 shows that red rot cull tended to vary directly with risk rating: the higher the risk rating, the higher the cull percent. Even Risk Class 4, with too small a basis for comparative purposes, had more cull than either Risk Class 1 or 2, and nearly as much as Risk Class 3.

Much the same relationship was apparent in individual age classes. For example, in Age Class III (actual age 151 to 225 years) low and moderate risk trees (Classes 1 and 2) contained

Table 3. --Relation of scaled red rot to diameter breast height in the virgin stand

Keen age class[1]	D.b.h. class	Average scaled red rot, by--				Basis: trees	
		Estimated age		Actual age		Estimated age	Actual age
		Volume	Cull	Volume	Cull		
	Inches	Bd. ft.	Pct.	Bd. ft.	Pct.	Number	
III	12-18	21	16	20	15	207	102
	20-26	51	14	35	10	247	73
	28-34	89	12	6	1	21	8
	36+	30	1	0	--	1	0
IV	12-18	34	21	27	19	23	106
	20-26	109	23	83	19	97	231
	28-34	206	20	204	20	53	64
	36+	427	20	391	18	10	11

[1] III = 151-225 years old; IV = more than 225 years old (Thomson, Walter G. A growth rate classification of southwestern ponderosa pine. J. Forest. 38: 547-553. 1940.)

70 percent of the gross volume and 48 percent of the red rot volume in the age class and had a rot cull percent of 7 as compared with 18 for high and very high risk trees (Classes 3 and 4). The relationship was less striking for Age Class IV trees (actual age 226 years and older): low and moderate risk trees contained 46 percent of the gross volume and 41 percent of the red rot volume in the age class, and had a cull percent of 17 as compared with 21 for high and very high risk trees.

Table 4. --Relationship of gross volumes and red rot volumes to risk ratings

Risk rating	Trees	Proportion of total		Red rot cull
		Gross volume	Red rot volume	
	No.	- - - - Percent - - - -		
1	272	20	7	6
2	394	37	35	14
3	272	36	49	20
4	70	7	9	18
Total or average	1,008	100	100	15

Because of previously discussed inaccuracies in estimating tree ages, the relationship between red rot and risk rating in Age Class III was not as strong when trees were classified according to estimated ages: 11 percent in low and moderate risk trees as compared with 18 percent in high and very high risk trees. In Age Class IV these percentages were 19 and 23.

Bark appearance as marking criterion.— Relation of red rot to age and other factors could not have been properly evaluated if actual ages of study trees had not been determined. Stump ring counts, however, are impractical except in experimental work where all trees are felled. For this reason, color and other characteristics of lower trunk bark were recorded to determine if they could be used as criteria of tree age or presence of red rot. Records were taken on 85 percent of the trees. This sample contained 85 percent of the gross volume in the overall sample, and had the same red rot cull percent.

Table 5 shows the distribution of gross volumes and scaled red rot volumes in the virgin stand according to estimated and actual ages and bark color. Percentages shown for estimated and actual ages approximate proportions shown in figure 6. When bark color was

Table 5.--Distribution of gross volumes and scaled red rot volumes in the virgin stand, according to estimated ages,[1] actual ages,[1] and bark color

Keen age class[1] or bark color	Basis: trees	Gross volume[2]	Scaled red rot volume[3]
	No.	Percent	
Estimated age:			
I & II	289	14	1
III	399	44	41
IV	161	43	58
Actual age:			
I & II	334	19	2
III	161	15	10
IV	354	67	88
Bark color:			
Blackjack	255	13	1
Intermediate	178	13	4
Yellow pine	416	74	95

[1] I = less than 75, II = 76-150, III = 151-225, IV = more than 225 years old (Thomson, Walter G. A growth rate classification of southwestern ponderosa pine. J. Forest. 38: 547-553. 1940.)

[2] As a proportion of total gross.

[3] As a proportion of total scaled red rot.

used as a criterion of age, 95 percent of the red rot volume in the virgin stand was accounted for by yellow pines that contained 74 percent of the gross volume.

Because 95 percent of total red rot volume occurred in trees classified as yellow pines, analysis of the relation of decay to other bark characters was restricted to this class. These characters were texture (smooth or shaggy), depth of furrows (shallow, moderately deep, or deep), and plate size (large, medium, and small). Shaggy bark seemed to be an almost certain indicator of red rot, but only 13 percent of the yellow pines containing 9 percent of the gross volume and 16 percent of the red rot volume had this characteristic. Other bark characteristics did not prove helpful.

Marking.—In addition to marking guides used in this study[7] there are other methods of marking to achieve the same objectives. Table 6 compares some alternative methods of marking by showing proportions of total gross volumes and red rot volumes that would be removed by using various criteria. A method is available to meet most cutting objectives; different methods would mark all the way from 33 to 86 percent of the total gross volume and 48 to 99 percent of the red rot. Methods 1 to 4 probably involve removal of more gross volume than is desirable under the light improvement selection method of harvest. There is little difference between methods 5, 6, and 7 in the proportions of total gross volumes and red rot volumes they would remove. Method 6 is simplest, however, and would be easiest to apply with perhaps the least chance of variation among markers.

Importance of red rot in the second cut.—Estimates of severity of red rot in the second cut are based on the assumption that trees in the residual stand will increase in gross volume and suffer red rot losses as indicated by the curves in figure 5. This assumption does not allow for any acceleration in growth, or for ingrowth, but in partially cut stands on the Navajo Reservation these two elements may not appreciably affect the cull percent that can be expected in the second cut. It is estimated that, in the 20 years following the first cut, gross volumes will increase about 14 percent (365 board feet per acre), and red rot volumes will increase about 27 percent (60 board feet per acre).

Red rot cull percent for the current residual stand is 9 percent. For the stand 20 years hence it is calculated to be 10 percent. It should average slightly more than 10 percent in the second 25-year cutting cycle. If method 6 (table 6) is adopted and a heavier cut (56 percent of the gross volume and 78 percent of the red rot volume) is made during the first cutting cycle, red rot cull should amount to 8 percent in the residual stand and a little more than 9 percent in the second cutting cycle.

With annual cuts of 34 million board feet, red rot losses in the Defiance and Chuska-Tsailee Units of the Navajo will amount to 7.5 million board feet (22 percent of the gross volume cut). Adoption of method 6 would result in a decrease in red rot cull percent to 21 but an increase in red rot volume losses

Table 6. --Comparison of the proportions of gross volumes and red rot volumes removed by using various criteria[1] for marking the virgin stand

Method No.	Marking criteria: Mark all--	Proportion of total volume removed[2]		Red rot cull[3]
		Gross	Red rot	
		- - - Percent - - -		
1	Keen class III and IV trees	86	99	17
2	Yellow-bark trees[4]	74	95	20
3	Risk class 2, 3, and 4 trees	80	93	17
4	Risk class 3, 4, and yellow-bark risk 2 trees	67	88	20
5	Risk class 4 and yellow-bark risk 2 and 3 trees	58	79	20
6	Yellow-bark risk class 2, 3, and 4 trees	56	78	21
7	Keen class IV, risk class 2, 3, and 4, plus Keen class III risk class 3 and 4 trees	54	76	21
8	Risk class 3 and 4 trees	43	58	20
9	Keen class IV trees	41	58	21
10	Keen class III and IV, risk class 3 and 4	42	57	21
11	Risk class 4 and yellow-bark risk 3 trees	34	49	21
12	Yellow-bark, risk class 3 and 4 trees	33	48	22

[1] Other criteria involve gross volumes too small to be practical.
[2] Gross and red rot volumes removed as a percent of respective total volumes.
[3] Average cull percent due to red rot in material removed.
[4] Trees with yellow bark on the butt log--not black or cinnamon.

(to 8.4 million board feet) because it would remove an additional 6 million board feet annually during the first cutting cycle. The larger cuts would more than offset the increased rot losses. Although it would be necessary to balance this overcutting by smaller cuts during the second cutting cycle, there would be considerably less red rot—13 percent under method 6 as compared with 15 percent of the gross volume cut, if the current marking policy is continued. In general, method 6 could be expected to increase net stumpage returns for the first two cutting cycles, while attacking the red rot problem at the most opportune time when available volumes are greatest.

Summary

Analysis of data from several hundred plots randomly located in the ponderosa pine forests of the Navajo Indian Reservation revealed that red rot cull caused by Polyporus anceps amounted to 15 percent of the gross volume of the virgin stand. Although the rot was found to be closely related to several factors studied, tree age was by far the most significant. Bark color in the lower trunk was a better criterion of red rot cull than broad age classes based on either actual or estimated ages. The analysis also showed that, under the current system of light improvement selection, the first cut removed 48 percent of the gross volume and 68 percent of the red rot volume (a cull percent of 22) leaving a residual stand with 9 percent of the gross volume already lost. This red rot will increase about 1 percent in 20 years. Hence, it will average slightly more than 10 percent during the second 25-year cutting cycle, and red rot cull will amount to about 15 percent of the gross volume cut in that cutting cycle. On the other hand, marking all yellow-barked trees (except low risk trees) in the first cutting cycle would remove 56 percent of the gross volume and 78 percent of the red rot volume. This would leave a residual stand with about 8 percent red rot that would increase to slightly more than 9 percent during the second cutting cycle. Red rot cull would then amount to only about 13 percent of the gross volume cut. In general, this method should increase stumpage returns and place major emphasis on reducing red rot losses in the first cutting cycle.

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Key words: Red rot, ponderosa pine, Navajo Indian Reservation

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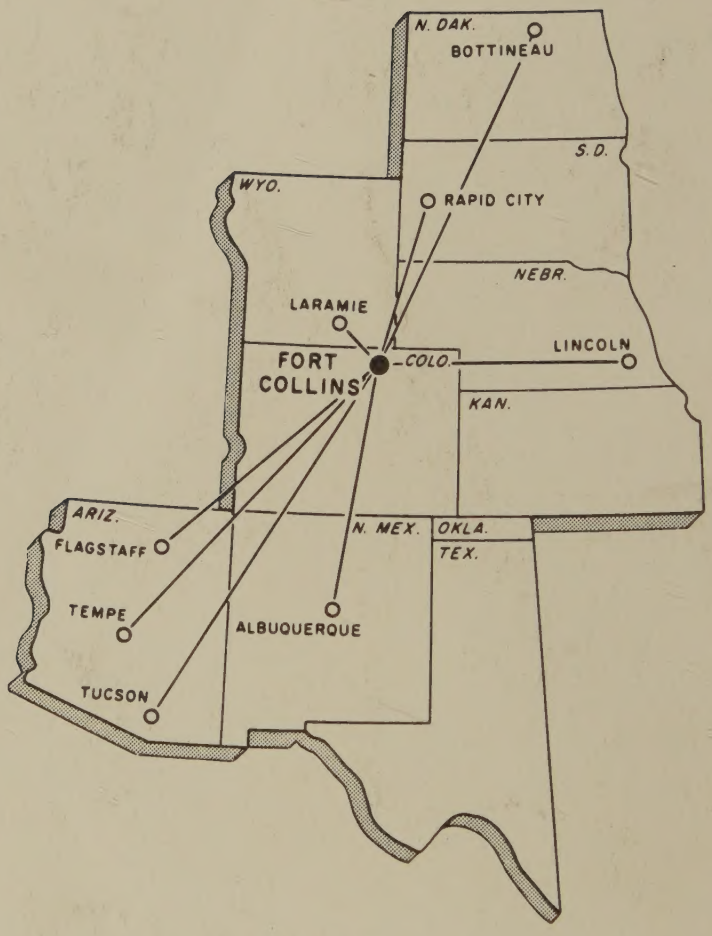
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